2.1 ELECTRICAL RESISTANCE TOMOGRAPHY FOR SUBSURFACE IMAGING

TECHNOLOGY NEED

Electrical Resistance Tomography (ERT) technology can be used for detecting leaks from the Hanford single-shell tanks. DOE has approximately 149 single-shell tanks that have been used to store high-level mixed wastes, many located at the Hanford site. It is known that 60 to 70 of these tanks were leaking and releasing their contents to the surrounding soil. Other tanks may be leaking, but the existing techniques for determining leakage prevents an accurate assessment. In line with the potential for danger such releases pose to site personnel and longer-term danger to the surrounding communities, environmental regulations require that even small volume releases from these tanks be reported. There is a clear need to be able to detect when a tank begins leaking so that corrective measures can be taken before damage is great. There is also a need to be able to isolate the leak location in the event that tank repairs are practical.

There are currently two methods for detecting leaks, and neither is useful for locating the precise location point. The simplest method is a careful inventory of tank contents. Unfortunately, the precision needed in level sensing is not simple with the nasty conditions in these tanks. Even level sensors are troublesome due to the large chunks of waste in some. The other approach is to drill beneath the tank and install sensors. This method also presents problems since these sensors provide point measurements under the tank, and any leakage will be highly channeled due to the heterogeneous soil at Hanford and will likely be missed.

In situ remediation of contaminated sites requires at least two activities. First, it is necessary to characterize the relevant parameters of the site (e.g., geology, hydrology, geochemistry). Second, it is necessary to monitor whatever method is used to accomplish the remediation in order to control the process and evaluate the final results. Current technology for both tasks is often based on drilling and sampling, which is expensive, invasive, and often produces a very sparse data set. A technology is needed to provide high-resolution information between boreholes. ERT is designed to fill in this missing information. A 2.5-dimensional code has proven useful for many applications, especially for cross-borehole imaging where the subsurface is approximately two dimensional. However, much of the world cannot adequately be approximated by two dimensions. There is a clear need for accurate three-dimensional images of subsurface properties and processes. Such a capability would be very valuable in environmental restoration work, as well as many other geophysical and geotechnical areas.

Much of the subsurface soil and groundwater contamination that DOE is required to cleanup is contaminated with nonaqueous phase liquids (NAPLs). Unfortunately, most of these liquids are very difficult to detect without drilling a borehole and testing a soil or water sample. Because the subsurface is usually very heterogeneous, a lot of drilling is needed for this approach to adequately map most contaminant plumes. A method is needed to look beneath the surface, or perhaps between boreholes, and map the three-dimensional extent of NAPL contaminants. This ability would make possible estimates of the contaminant mass, lateral extent of the plume, speed and direction of transport, and would greatly aid in designing remediation strategies.

TECHNOLOGY DESCRIPTION

The goals of this task are to: (1) develop and demonstrate a system for detecting and locating leaks in the single shell tanks at the Hanford Site; (2) develop a practical, fully three-dimensional inverse code for ERT; and (3) extend research and development for detection of NAPLs by a small-scale ERT imaging experiment of a trichloroethylene (TCE) or polychloroethylene (PCE) release at the Oregon Graduate Institute (OGI) LEAP tank facility.

BENEFITS

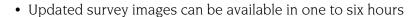
The technique is based on the automated measurement and computerized analysis of electrical resistivity changes caused by natural or man made processes, such as surface water infiltration, underground tank leaks, and steam or electrical heating during soil cleanup.

ERT has a variety of applications:

- Site characterization in soil remediation projects
- Detection and location of subsurface leaks
- Evaluation of effectiveness of cleanup techniques
- Cleanup process control
- Nondestructive evaluation of large structures such as pavements, buildings, and dams

ERT has strong advantages over competing techniques:

- Provides unprecedented detail of subsurface structures and processes (resolution is roughly equal to electrode separation)
- Two- and three-dimensional imaging is possible
- 50% to 75% fewer boreholes are needed than in conventional boreholesampling techniques



- Effective at depths of 10 to 500 ft.
- Stainless steel electrodes are rugged, inexpensive, and easily emplaced
- ERT has been demonstrated in both clay-rich and sandy soils

COLLABORATION/TECHNOLOGY TRANSFER

Collaboration is ongoing with SteamTech Inc., an environmental remediation service company, to transfer the basic ERT technology. That work began in FY95 and continued into FY96. Collaboration is also ongoing with Prof. Douglas LaBrecque at the University of Arizona and with Prof. Andrew Binley at the University of Lancaster, England. Their contributions to the project are mainly computer code development. Collaboration is ongoing with Westinghouse Hanford Co. (EM-40), in the development of tank leak detection technology. Collaboration is also ongoing with Rick Johnson at the OGI in the NAPL experiment.

ACCOMPLISHMENTS

Detecting leaks from the Hanford underground, single-shell tanks is a continuing task. At the DOE Hanford Site, a storage tank test facility has been constructed that can be used to test schemes for detecting tank leaks. This facility has been used for two tests in FY94, which were designed to use electrical resistivity images under the tank to detect and locate leaks. The first test was for a 'bath-tub ring' leak where water was released from the tank along one side, and ERT images under the tank were successful in following the plume of water in the soil as a function of time and space down to a depth of 35 feet (the limit of our electrodes). The second test was for a leak from the tank bottom, where water was released from beneath the tank.

Development of a fully three-dimensional ERT code is underway. A test version of the three-dimensional inversion code has been written. It incorporates a new version of the forward solver, which is designed to be more accurate and faster than the previous solver. Initial tests were on synthetic data and some limited tests have been on field data. The performance remains very slow—inversions of typical data sets require one to three days of Central Processing Unit (CPU) time on a Sun Sparc 5 workstation.

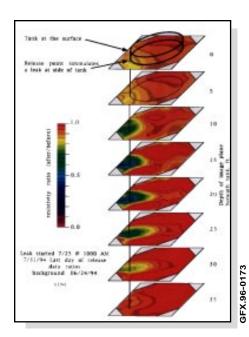


Figure 2.1-1 The figure shows a series of twodimensional, horizontal
tomographs which show the
decreases in soil electrical
resistivity below a metal tank at the
200 East area of the Hanford
reservation. The location of the
release point and the outline of the
tank's perimeter are shown for
reference. The tomographs show
resistivity decreases where a salt
water solution invaded the soil.

Imaging NAPLs at the OGI LEAP tank is a new task. The tank was prepared for the experiment in early spring of 1995, the experiment was conducted in the summer of 1995, and the tank cleanup will be accomplished (and funded) in FY96. The experiment consisted of releasing a DNAPL (PCE) into a water-saturated sandy loam that has two low-permeability clay layers to impede downward movement. Before, during, and after the release, ERT images were made of both resistivity and chargability.

TTP INFORMATION

Electrical Resistance Tomography For Subsurface Imaging technology development activities are funded under the following technical task plan (TTP):

TTP No. SF24C223 "Electrical Resistance Tomography For Subsurface Imaging"

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